RETRIEVAL AND PREDICTION OF EXTREME PRECIPITATION

Underestimated Extreme Precipitation Exposed by Comparisons of TRMM and WSR-88D Data

Alexandria Gingrey, Adam Varble, and Ed Zipser
Department of Atmospheric Sciences, University of Utah

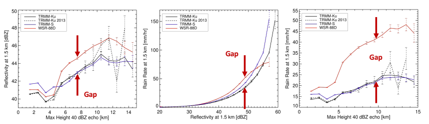
MOTIVATION AND METHODOLOGY

Heavy precipitation causes attenuation of TRMM PR and GPM DPR signals that requires correction, but is this attenuation correction unbiased with respect to convective intensity? We know that convective intensity differs significantly over land and ocean, and therefore, retrieval of extreme rain rates could potentially be geographically biased. To evaluate this possibility, we statistically compare TRMM retrievals of rain rate to WSR-88D retrievals of rain rate in the context of low level reflectivity and maximum height of the 40 dBZ echo, which has been shown to be a proxy for convective intensity.

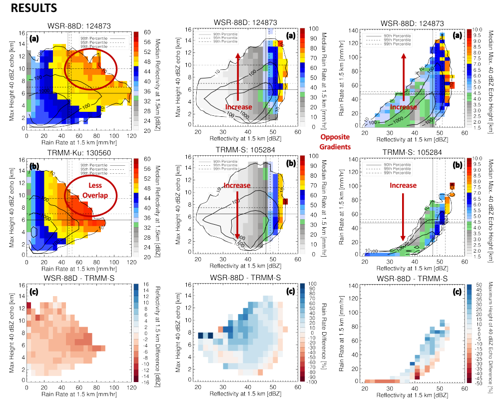
To make comparisons between TRMM and WSR-88D, individual columns are considered rather than entire systems. June-August (JJA) 2013 data from 28 dual-polarimetric WSR-88D radars over the SEUS are Cartesian gridded at 1.125 km horizontal and 250 m vertical spacing. Rain rates are retrieved using the CSU-HIDRO algorithm that situationally chooses between Z-R, Z-ZDR, Z-ZDR-KDP, and Z-KDP relationships (Cifelli et al. 2013). Data is averaged down to 4.5 km horizontal spacing to approximately match the TRMM resolution. To include entire columns, data are limited to between 40 and 80 km ranges from each radar. JJA 2002-2013 TRMM 2A25 V7 retrievals within 80 km range of each of the WSR-88D radars is converted from Ku-band to S-band using the conversion factors in Cao et al. (2013) – rain below 4-km altitude and hail above 5-km altitude. The greater of the TRMM and WSR-88D sample sizes for each radar are randomly sub-sampled to the lesser sample size so that sample sizes are equal for each of the 28 radars considered.

Comparisons focus on 1.5-km altitude reflectivity, 1.5-km altitude rain rate, and maximum 40 dBZ echo height. TRMM path integrated attenuation (PIA), as well as WSR-88D differential reflectivity (ZDR), specific differential phase (KDP), and hail fraction (areal fraction of hail, graupel, and mixed hail/rain points from particle identification algorithm) are also analyzed but not shown here.

RESULTS



For a given maximum 40 dBZ height above 5 km, mean WSR-88D 1.5-km altitude reflectivity is consistently 1.5 dB greater (above left). Retrieved mean rain rates for reflectivities < 52 dBZ are also greater (above middle), likely from incorporation of KDP in WSR-88D retrievals. These differences combine to produce WSR-88D mean rain rates that are nearly double those of TRMM for a given maximum 40 dBZ height (above right). TRMM retrievals from 2013 alone when WSR-88D retrievals are used show that 2013 is likely not an anomalous summer relative to the 2002-2013 period from which TRMM retrievals are used.



In the leftmost column to the right, max. 40 dBZ height-1.5 km rain rate joint histograms are filled with median 1.5 km reflectivity. Extreme rain rates occur most frequently for max. 40 dBZ heights of ~6 km, but the overlap of extreme max. 40 dBZ heights and rain rates is ~50% greater for WSR-88D than TRMM. TRMM has greater median 1.5 km reflectivities for all max. 40 dBZ height-rain rate combinations.

In the middle column to the right, max. 40 dBZ height-1.5 km reflectivity joint histograms are filled with median 1.5 km rain rate. TRMM rain rates are up to 70% lower than WSR-88D for max. 40 dBZ heights above the melting level and moderate 1.5 km reflectivities. For a given 1.5 km reflectivity, WSR-88D rain rate increases with max 40 dBZ height, but the opposite is true for TRMM.

In the rightmost column to the right, 1.5 km rain rate-reflectivity joint histograms are filled with median max. 40 dBZ height. WSR-88D rain rates are more variable than TRMM for a given reflectivity, and TRMM max. 40 dBZ heights decrease as rain rate increases for a given 1.5 km reflectivity. WSR-88D exhibits the opposite pattern.

WSR-88D retrieved rain rates are double those retrieved by TRMM 2A25 V7 for situations in which maximum 40 dBZ heights exceed 5-km altitude. This is caused by low level reflectivities that are greater for WSR-88D than TRMM for a given maximum 40 dB height and rain rates that are greater for WSR-88D than TRMM for a given low level reflectivity. While WSR-88D rain rates increase with maximum 40 dBZ height for a given 1.5 km reflectivity, the opposite is true for TRMM 2A25. Relatively large PIA, ZDR, KDP and hail fraction values for 1.5 km reflectivities exceeding ~45 dBZ or maximum 40 dBZ heights exceeding ~5-km altitude indicate unique particle size distributions that may be different than what is assumed in TRMM 2A25 V7, in which phase and size distribution profiles need to be assumed. This combined with potentially incorrect PIA estimates caused by non-uniform beam filling and/or biased surface reflectivity estimates in these convectively intense situations likely produce low biased near-surface TRMM attenuation-corrected reflectivities and rain rates, while assumed Z-R relationships may further increase rain rate low biases. Results have been submitted to the Journal of Applied Meteorology and Climatology.

REFERENCES: Cao, Q., and coauthors, 2013: Empirical conversion of the vertical profile of reflectivity from Ku-band to S-band frequency. *J. Geophys. Res.*, *118*, 1814–1825.

Cifelli, R., and coauthors, 2011: A new dual-polarization radar rainfall algorithm: Application in Colorado precipitation events. *J. Atmos. Oceanic Tech.*, *28*, 352–364.

Relationships of Extreme Precipitation Event Properties With Surface and Environmental Conditions

Crystal Painter, Adam Varble, and Ed Zipser
Department of Atmospheric Sciences, University of Utah

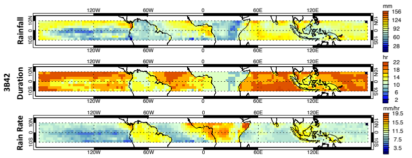
MOTIVATION AND METHODOLOGY

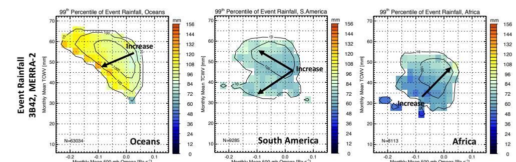
Rainfall is critical to societal and ecosystem health, but the frequency and intensity of rainfall are also important because they affect whether rainfall goes into the ground or whether it flows to another location. Therefore, prediction of rainfall event characteristics is a critical component of predicting important regional climate conditions. In particular, extreme precipitation events have significant impacts on society and ecosystems. To predict them, we must understand the ways in which they depend on large-scale environmental conditions that cause precipitation to develop, and use these relationships to evaluate weather and climate models that we rely on for societal decision making.

12 years of 3B42 retrievals and 2 years of IMERG retrievals are used to define rainfall events by connecting contiguous periods with at least 1 mm h^{-1} rainfall for each 3B42 and IMERG pixel location at their native resolutions of 0.25° and 0.1°, respectively. These events are then accumulated in 2.5° grid boxes for each month of each dataset across the tropics from 10°S to 10°N and the number of events, event duration, mean event rain rate, and event total rainfall are computed. The 99th percentile of event duration, rain rate, and rainfall for each month and 2.5° grid box are computed and deemed to be "extreme" event properties for that month and location.

Each monthly grid box extreme rainfall event property is then matched with a monthly mean total column water vapor (TCWV), 500-hPa vertical motion (omega), and surface elevation that corresponds with that 2.5° grid box and month. These environmental conditions are derived from MERRA-2 and ERA-Interim reanalyses, although only MERRA-2 results are shown below. Any month in any 2.5° grid box that has less than 3 mm day^{-1} of GPCP rainfall is removed from the analysis to ensure sufficient sampling of rainfall events. Therefore, the relationships between rainfall events and environmental conditions shown here apply to regions and months with at least moderate rainfall. Although the number of events, along with duration and rain rate are analyzed in addition to less extreme events, only 99th percentile event rainfall is highlighted below because of space restrictions.

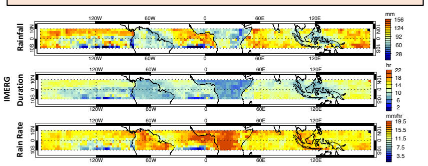
RESULTS

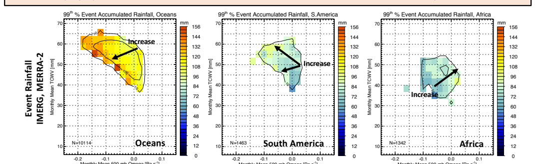




Extreme event rainfalls are lower over land than ocean, with slightly higher overall values retrieved by IMERG than 3B42. Extreme event durations are shorter over land than ocean with longer durations over South American and the Maritime Continent than Africa. Extreme event rain rates, however, are higher over land than ocean with higher values over Africa than South America and the Maritime Continent. IMERG gives shorter durations and higher rain rates than 3B42, which is expected given its higher resolution, but geographical variability is similar between the datasets.

Mean extreme event rainfall increases with 500-hPa vertical motion over oceans and South America, but decreases with increasing rising motion over Africa. While rainfall increases with TCWV over Africa, it decreases with TCWV over oceans when controlling for vertical motion. Over South America, a bimodal pattern with respect to TCWV is present. The higher rainfalls at lower TCWV values are produced over higher elevations, and thus, elevation is a key variable to consider. Although the IMERG sample size is much smaller than 3B42, values are only slightly different, and extreme event rainfall varies with TCWV and 500-hPa vertical motion similarly.





Multiple linear regression on TCWV, 500-hPa omega, and elevation reasonably reproduces the mean extreme event property values, but with large spread for a given TCWV-omega-elevation condition. Some relationships between events and environmental conditions have regression coefficients that significantly differ between 3B42-MERRA, IMERG-MERRA, 3B42-ERA, and IMERG-ERA datasets in terms of sign and magnitude while others do not (not shown). However, ERA-Interim produces generally similar results to MERRA-2. Standardized regression coefficients were used to compare the importance of 500-hPa vertical motion vs. TCWV in affecting event characteristics. Greater correlation of event properties with omega over oceans and TCWV over land may be related to diurnal cycle, low level forcing, RH, and lapse rate differences. These results should be used to evaluate model predicted relationships between extreme rainfall events and environmental conditions.

ACKNOWLEDGEMENTS: We thank NASA for funding this work under grant NNX16AD76G and providing TRMM, GPCP, and MERRA-2 data. We also thank NOAA NCDC for providing NEXRAD data, Mike Dixon at UCAR for providing RadX software, ECMWF for providing ERA-Interim data, and the Center for High Performance Computing at the University of Utah for computing and data storage resources.

CONTACT: Ed Zipser, ed.zipser@utah.edu